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E. Losee, et al

Watervliet Arsenal

Prepared for:

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September 1973

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INDEX TO WATERVLIET ARSENAL TECHNICAL REPORTS, 1973

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WVT SP-74044

TABLE OF CONTENTS

	PAGE
AUTHOR INDEX	1 - 2
SUBJECT INDEX	3 - 10
ABSTRACTS	11 - 62

Key: The numbers of memorandum reports are preceded by the letter M; those of technical reports, by T. Report numbers followed by an asterisk indicate technical reports that have appeared in open literature.

AUTHOR INDEX

Ahmad, I. R-WV-N-6-9-73*

Alix, L.J. R-WV-T-18-73

Anderson, Gary L. R-WV-T-6-50-73 R-WV-T-2-46-73 R-WV-T-2-14-73

Brassard, T.V. R-WV-T-6-49-73*

Carofano, Garry C. H-WV-T-1-11-73 R-WV-T-6-12-73

Chen, P.C.T. R-WV-T-6-32-73*

Cheng, Y.F R-WV-T-6-40-73 R-WV-T-6-41-73

Costantino, D. M-WV-T-1-23-73

Davidson, T.E. R-WV-T-1-1-73 R-WV-T-6-20-73

DeFries, R.S. R-WV-T-6-49-73*

Dembowski, P.V. R-WV-T-6-20-73

Ferguson, Martin S. R-WV-T-6-43-73

Frankel, Herbert R-WV-T-1-53-73

Fujczak, R.R. R-W-T-1-1-73

Gray, A. Marcus R-WV-N-6-33-73

Huang, Y. K. M-WV-T-1-10-73

Hussain, M. A. R-WV-T-6-31-73** R-WV-T-6-48-73** R-WV-T-6-29-73 R-WV-T-6-13-73** R-WV-T-X-6-73

Imam, A. R-WV-T-18-73

John, F. J. R-WV-T-1-17-73

Kendall, D. P. R-WV-T-6-39-73 R-WV-T-6-15-73 R-WV-T-X-6-73

loomis, K. E. R-WV-N-6-9-73*

Lorenson, W. E. R-WV-T-X-6-73

Meisel, Lawrence V. R-WV-T-1-7-73

Milligan, R. V. R-WV-Y-6-42-73*

Montuori, V. H. M-WV-T-3-47-73

Nolan, C. J. R-WV-T-6-49-73**

O'Hara, G. Peter R-W-T-6-52-";

AUTHOR INDEX

Pepe, Joseph R-WV-T-6-16-73 R-WV-T-6-20-73

Perko, C. M-WV-T-1-25-73 M-WV-T-1-23-73

Pflegl, G. A. R-WV-T-1-11-73

Powis, H. M-WV-T-1-35-73 M-WV-T-1-36-73 M-WV-T-1-37-73

Pu, S. L. R-WV-T-6-31-73* R-WV-T-6-13-73 * R-WV-T-6-29-73 R-WV-T-6-48-73 * R-WV-T-X-6-73

Racicot, Ronald L. R-WV-T-6-51-73 R-WV-T-6-22-73 R-WV-T-6-12-73 R-WV-T-1-1-73

Responser, Herman J. R-WV-S-3-5-73

Rosenberger, W. F. M-WV-T-1-30-73 M-WV-T-1-21-73

Saegusa, Fumihiko R-WV-T-X-02-7

Scanlon, R. D. R-WV-T-6-48-73*
R-WV-T-6-15-73

Scavullo, Maurice A. R-WV-T-6-12-73

Simkins, Thomas E. R-WV-T-6-12-73

Soanes, Royce W. R-WV-S-6-38-73

Thomas, Charles R. R-WV-T-6-45-73 R-WV-T-6-44-73 R-WV-T-X-8-73 R-WV-T-X-28-73 R-WV-T-X-24-73 R-WV-T-X-4-73*

Throop, J. F. R-WV-T-1-1-73

Underwood, J. H. R-WV-T-6-39-73 R-WV-T-6-29-73 R-WV-T-6-15-73

Vasilakis, John D. R-WV-T-6-12-73 N-WV-T-3-19-73 R-WV-T-1-3-73

Warenchak, R. A. R-WV-N-6-9-73 *

Winters, D. C. R-WV-T-6-39-73

Wu, Julian J. R-WV-T-2-27-73

Additives	Blast
M-WV-T-1-21-73	M-WV-T-1-10-73
Aircraft	Boron
R-WV-T-X-8-73	R-WV-T-6-40-73
	R-WV-T-6-41-73
Airframes	· · · · · ·
R-WV-T-X-8-73	Houndaries
N 111 X X G 13	R-WV-T-2-27-73
Ammunition Damage	R-WV-T-X-28-73
M-WV-T-1-35-73	1 11 1 2 20 17
M-WV-T-1-36-73	Boundary Layer
	R-VV-T-6-48-73 *
M-WV-T-1-37-73	K-414-1-0-40-(2)
Anna dadan Marakandana	Boundary Value Problems
Ammunition Feed Mechanisms	R-WV-T-6-31-73 *
M-WV-T-1-23-73	H-WV-T-0-31-73
Approximation (Mathematics)	Breech Mechanisms
R-WV-T-6-15-73	R-WV-T-6-52-73
V-MA-1-0-13-13	K-WA-1-0-75-17
Autofrettage	Calculus of Variations
M-WV-T-1-25-73	R-WV-T-2-14-73
H-#V-1-1-2)-/)	R-WV-T-6-26-73
tutometés Vannens	R-WV-T-6-44-73
Automatic Weapons	R=WV-T=6=31=73
M-WV-T-1-25-73	R-WV-T-2-27-73
R-WV-T-6-12-73	K-WV-1-2-2(-1)
R-WV-T-1-3-73	* * * * * * * * * * * * * * * * * * *
M-WV-T-1-23-73	Calibration
	R-WV-T-6-15-73
Bainite	R-WV-T-X-6-73
R-WV-T-6-49-73*	
	Cams
Bayes' Theorem	M-WV-T-3-47-73
R-WV-T-6-51-73	
R-WV-T-1-1-73	Cantilever Beams
R-WV-T-6-22-73	r-wv-t-6-26-73
-	
Beams (Structural)	Cartridge Case Extractor:
R-WV-T-6-45-73	M-WV-T-1-23-73
R-WV-T-6-26-73	
R-WV-T-6-50-73	Compusite Materials
R-WV-T-6-44-73	R-W -T-6-40-73
R-WV-T-2-14-73	R-W-T-6-20-73
R-WV-T-2-46-73	R-WV-S-6-38-73
E 17	R-WV-T-X-4-73*
	R-WV-T-6-48-13*

Composite Materials cont.	Deformation cont.
R-WV-T-1-7-73	R-WV-T-2-46-73
R-WV-T-6-41-73	R-WV-T-6-50-73
R-WV-T-6-43-73	
R-WV-T-6-45-73	Design
R-WV-T-6-48-73*	M-WV-T-1-25-73
	R-WV-T-1-7-73
Computations	R-WV-S-3-5-73
R-WV-T-6-51-73	M-WV-T-3-19-73
R-WV-T-6-26-73	M-WV-T-1-30-73
R-WV-T-6-44-73	11-11-10-75
R-WV-T-2-27-73	Differential Equations
R-WV-T-6-22-73	R-WV-T-2-14-73
R-WV-T-1-21-73	R-WV-T-X-24-73
R-WV-S-6-38-73	R-WV-T-2-27-73
R-WV-T-6-32-73	R-WV-T-X-28-73
R-WV-T-6-51-73	K-WV-1-X-20-73
R-WV-T-6-9-73*	Description Automobile
R-WV-T-1-11-73	Drafting, Automatic
R-WV-T-6-29-73	M-WV-T-3-47-73
k-WV-T-6-15-73	B44544
R-WV-T-2-14-73	Ductility
R-WV-N-6-33-73	R-WV-T-6-20-73
N-#Y-N-0-33-73	713 4.1 - P 4.1
Computer Applications	Elastic Properties
M-WV-T-3-37-73	R-WV-T-6-29-73
9-WV-T-6-22-73	R-WV-T-X-28-73
10-47-1-0-22-75	R-WV-T-X-4-73
Corresive Gases	R-WV-T-X-8-73
R-WV-T-X-02-73	R-WV-T-6-45-73
11-11-1-1-102-75	R-WV-T-2-46-73
Crack Propagation	R-WV-T-6-31-73*
H-WV-T6-29-73	R-WV-T-6-32-73*
R-WV-T-6-39-73	R-WV-T-X-24-73
R-WV-T-6-48-73*	R-WV-T-6-42-73
	R-W-T-6-52-73
R-WV-T-X-02-73 R-WV-T-6-13-73*	R-WV-T-1-11-73
V-MA-1-0-T)-(')*	
Dawning	Energy Bands
Damping	R-WV-N-6-33-73
R-WV-T-2-14-73	
R-WV-T-2-27-73	Energy Transfer
R-WV-T-2-46-73	R-WV-T-6-29-73
Deformation	Warner Danda -
R-WV-T-6-32-73#	Epoxy Resins
R-WV-T-6-16-73	R-WV-T-6-43-73
N HT 1 0 10-17	

Equations	Firing Tests (Ordnance)
R-WV-T-6-50-73	R-WV-T-1-1-73
R-WV-T-X-4-73*	R-WV-T-1-3-73
R-WV-T-6-26-73	R-57-T-X-02-73
R-WV-T-6-44-73	M-WV-T-1-23-73
R-WV-T-6-29-73	
R-WV-T-6-31-73*	Flow
R-WV-T-2-46-73	R-WV-T-6-32-73 *
R-WV-T-6-44-73	M-WV-T-1-10-73
R-WV-T-2-14-73	
R-WV-T-X-24-73	Flutter
R-WV-T-2-27-73	R-WV-T-2-14-73
R-WV-T-6-45-73	R-WV-T-6-26-73
11-11-1-0-47-17	R-WV-T-6-44-73
Equations of Motion	R-WV-T-2-46-73
R-WV-1'-2-46-73	R-WV-T-6-45-73
R-WV-T-6-50-73	10-47-17
K-M4-1-0-20-12	Forging
	R-WV-T-X-8-73
Erosion	R-WV-T-6-39-73
R-WV-T-18-73	
/·	R-WV-T-6-49-73
Extrusion	Washing (Mashandan)
R-WV-T-6-16-73	Fracture (Mechanics)
	R-WV-T-6-29-73
Fabrication	R-WV-T-X-6-73
M-WV-T-1-25-73	R-WV-T-6-13-73 *
M-WV-T-1-30-73	R-WV-T-6-15-73
H-WV-1-1-3073	R-WV-T-6-16-73
Failure	R-WV-T-6-20-73
M-WV-T-1-23-73	R-WV-T-6-39-73
M-WV-T-1-35-73	r-wv-t-6-48-73 *
M-WV-T-1-33-73	
M-WV-T-1-37-73	Gas Dynamics
R-WV-T-6-40-73	M-WV-T-1-10-73
R-WV-T-6-41-73	
R-WV-T-6-22-73	Gun Barrels
K-WV-1-0-22-13	M-WV-T-1-30-73
Fatigue (Mechanics)	M-WV-T-1-25-73
R-WV-T-1-1-73	R-WV-T-1-3-73
K-MA-1-1-12	R-WV-T-1-1-73
Feeding (supplying)	R-WV-T-X-4-73
R-WV-S-3-5-73	R-WV-T-1-7-73
K-WV-5-3-7-7	R-WV-T-18-73
T11	M-WV-T-3-19-73
Fibers	M-WV-T-1-21-73
R-WV-T-6-40-73	M-WV-T-1-23-73
R-WV-T-6-41-73	M-WV-T-1-35-73
	M-WV-T-1-36-73
Filaments	M-WV-T-1-37-73
R-WV-S-6-38-73	
m. 1 14 15 14 1111 (Ammunda)	
Firing Mechanisms (Ammunition)	
R-WV-S-3-5-73	

Gun Barrels cont. R-WV-T-1-53-73 R-WV-T-6-43-73 M-WV-T-1-10-73

Guns, 20-30 mm M-WV-T-1-25-73 M-WV-T-1-23-73

Guns, 105 mm M-WV-T-1-35-73

Guns, 152 mm M-WV-T-3-19-73

Guns, 155 mm M-WV-T-1-37-73 R-WV-T-1-53-73

Guns, 175 mm M-WV-T-1-36-73

Hamiltonian Functions R-WV-T-6-26-73 R-WV-T-6-44-73

heat Transfer R-WV-T-6-12-73 R-WV-T-18-73 R-WV-T-2-27-73

Helicopter Rotors R-WV-T-X-4-73*

High Pressure M-WV-T-1-25-73 M-WV-T-1-10-73 R-WV-T-6-20-73

High Strength Alloys R-WV-T-1-3-73 R-WV-T-X-02-73

High Temperature M-WV-T-1-25-73 R-WV-T-1-3-73

Howitzers R-WV-S-3-5-73 Hydrostatics R-WV-T-6-16-73 R-WV-T-6-20-73

The second control of the second control of

Ignition Lag
R-WV-S-3-5-73

Impact Strength R-WV-T-6-49-73*

Integral Equations R-WV-T-6-29-73 R-WV-T-6-31-73* R-WV-T-6-32-73*

Intensity R-WV-T-X-6-73 R-WV-T-6-13-73* R-WV-T-6-15-73 R-WV-T-6-20-73

Interfaces M-WV-T-3-19-73 R-WV-T-6-31-73*

Interior Ballistics M-WV-T-1-30-73

Intermetallic Compounds R-WV-T-6-42-73*

Kinematics R-WV-T-2-46-73

Laminates R-WV-T-X-24-73 R-WV-T-X-4-73* R-WV-T-X-8-73 R-WV-T-5-45-73

Literature Surveys M-WV-T-3-19-73 R-WV-T-18-73

Loads (Forces)
R-WV-T-6-13-73*

The state of the s

Loads (Forces)	cont
R-WV-T-1-17-73	
R-WV-T-2-14-73	
R-WV-T-1-3-73	
R-WV-T-2-27-73	
R-WV-T-2-46-73	

Low Density R-WV-N-6-9-73*

Lubrication M-WV-T-1-23-73

Martensite
R-WV-T-6-49-73*

Mass R-WV-N-6-9-73*

Materials M-WV-T-1-25-73 R-WV-T-6-32-73* R-WV-T-6-20-73 R-WV-T-6-42-73* R-WV-T-6-43-73

Mathematical Models R-WV-T-6-12-73

Measurement R-WV-T-1-53-73

Mechanical Properties
R-WV-T-6-49-73*
R-WV-T-6-41-73
R-WV-T-6-39-73
R-WV-T-5-39-73
R-WV-T-X-28-73
R-WV-T-X-24-73
R-WV-T-X-4-73*
R-WV-T-3-4-73*
R-WV-T-6-45-73*
R-WV-T-6-32-73*
R-WV-T-6-32-73*
R-WV-T-6-32-73*

Metals M-WV-T-3-19-73 R-WV-T-6-20-73

Motal Seals M-WV-T-3-19-73

Metallurgy R-WV-T-6-16-73 R-WV-T-6-49-73

Microstructure R-WV-T-X-28-73 R-WV-T-X-8-73 R-WV-T-X-4-73 * R-WV-T-X-24-73 R-WV-T-6-45-73 R-WV-T-6-49-73 *

Modulus of Elasticity R-WV-T-X-28-73 R-WV-T-X-24-73 R-WV-T-X-4-73* R-WV-T-6-45-73 R-WV-T-6-39-73

Muzzle Brakes R-WV-T-1-17-73

Muzzle Velocity M-WV-T-1-30-73 M-WV-T-1-25-73 M-WV-T-1-21-73

Nozzles M-WV-T-1-10-73

Numerical Analysis R-WV-T-1-11-73 R-WV-T-2-27-73 R-WV-T-6-41-73

Oscillators R-WV-T-1-53-73

Oxidation R-WV-T-X-02-73

Phase Transformations R-WV-T-6-42-73*

Photoelasticity R-WV-T-6-52-73

Plastic Deformation R-W'-T-6-42-73*

Plastic Properties R-WV-T-6-32-73* R-WV-T-6-42-73*

Plates R-WV-T-X-28-73 R-WV-T-X-24-73 R-WV-T-X-4-73* R-WV-T-6-32-73* R-WV-T-6-45-73

Primers
R-WV-S-3-5-73

Frofiles
R-WV-T-18-73

Programming Languages
M-wV-T-3-47-73

Propellants 6-WV-S-3-5-73 M-WV-T-1-21-73

Rates R-WV-T-6-22-73

Recoilless Guns M-WV-T-1-10-73

Regression Analysis M-WV-T-1-21-73 M-WV-T-1-30-73 Reliability R-WV-T-6-12-73 R-WV-T-6-22-73

The state of the s

Residual Stress R-WV-T-6-32-73*

Rotation R-WV-T-6-50-73

Rupture R-WV-T-6-16-73 R-WV-T-6-20-73

Scale M-WV-T-1-10-73

Shear Stresses R-WV-T-1-17-73

Shock Waves M-WV-T-1-10-73

S1 (442) R-WV-N-6-33-73

Small Arms R-WV-T-1-3-73

Stability R-WV-T-2-14-73 R-WV-T-6-26-73 R-WV-T-2-27-73 R-WV-T-6-44-73 R-WV-T-6-50-73

Statistical Analysis R-WV-T-6-51-73 R-WV-T-1-1-73 R-WV-T-6-22-73

Steel R-WV-T-X-02-73 R-WV-T-17-73

And the same states to the same of the sam

Steel cont. M-WV-T-1-25-73 R-WV-T-6-49-73* R-WV-T-1-7-73 R-WV-T-6-39-73

Stiffness R-WV-T-X-28-73 R-WV-T-X-24-73 R-WV-T-X-4-73* P-WV-T-6-45-73

Strain (Mechanics) R-WV-T-5-42-73*

Strength (Mechanics) R-WV-T-6-40-73 R-WV-T-6-49-73*

Stress Analysis R-WV-T-X-C-73 R-WV-T-1-17-73 R-WV-T-6-52-73

Stress Concentration R-WV-T-6-41-73

Stress Corrosion R-WV-T-X-02-73

Stresses R-WV-T-6-12-73 R-WV-T-X-6-73 R-WV-T-X-8-73 R-WV-T-1-17-73 R-WV-T-6-13-73* R-WV-T-6-15-73 R-WV-T-6-16-73 R-WV-T-6-20-73 R-WV-T-2-27-73 R-WV-T-6-32-1/3* R-WV-T-6-40-73 R-#Y-T-6-41-73 R-WV-T-6-50-73 R-WV-T-6-52-73 R-WV-T-6-48-73* R-WV-T-1-17-73

Temperature R-WV-T-18-73 R-WV-T-1-53-73

Tensile Properties R-WV-T-6-43-73 R-WV-T-6-49-73*

Tension R-WV-T-6-41-73

Test Methods R-WV-T-6-39-73 R-WV-T-6-42-73* R-WV-T-6-43-73 R-WV-T-6-49-73* R-WV-T-6-29-73

Theory R-WV-T-6-32-73* R-WV-T-6-26-73 R-WV-T-6-44-73 R-WV-T-6-50-73 R-WV-T-X-28-73

R-WV-T-6-45-73

Thermal Properties R-WV-T-18-73

Thermistors R-WV-T-1-53-73

Thermoelasticity R-WV-T-2-27-73

Thermomechanics R-WV-T-2-27-73

Thermosetting Plastics R-WV-T-6-43-73

Thickness M-WV-T-1-25-73

Thick Walled Cylinders R-WV-T-6-39-73

Thick Walled Cylinders R-WV-T-1-3-73 R-WV-T-6-15-73 R-WV-T-X-6-73 R-WV-T-1-7-73

Topography M-WV-T-3-19-73

Toughness R-WV-T-6-43-73

Transitions R-WV-T-6-49-73 * R-WV-T-6-20-73 R-WV-T-6-42-73 *

Ultrasonic Tests R-WV-T-6-39-73

Vibration R-WV-T-2-46-73 R-WV-T-6-22-73 R-WV-T-6-12-73 R-WV-T-5-13-73 * R-WV-T-2-14-73 R-WV-T-2-4-73 R-WV-T-X-28-73 R-WV-T-5-28-73 R-WV-T-6-50-73

Warning Systems R-WV-T-1-53-73

Wave Propagation R-WV-T-X-8-73

Wear M-WV-T-1-21-73

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4 DESCRIPTIVE NOTES (Type of coper; and inclusive dates)	
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	U.S. Army Weapons Command
13. ABSTRACT	
Fatigue test results from cannon i	tubes fired to failure, tubes alternately

Fatigue test results from cannon tubes fired to failure, tubes alternately fired and laboratory cycled to failure, tubes fired and subsequently laboratory cycled to failure and tubes laboratory cycled only to failure are analyzed.

Point estimates and confidence intervals on the correlation factor \mathbf{k} in the expression

X = Rounds + k(cycles)

are determined, assuming a lognormal distribution law for the random variable X, the fatigue life expressed in fired rounds, and using Bayesian methods for obtaining confidence limits.

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11 ABSTRACT			
Commentary of high assessed asset			

Corrosion of high strength steel in gaseous environment is largely divided in two areas, high temperature oxidation and stress corrosion cracking at lower t $^{\rm tr}$, $^{\rm tr}$ and the stress. High temperature oxidation of the 4330 steel was conducted in CO-CO $_2$ mi resup to 1300°C. The reaction includes decarburization, internal and external oxidation depending on the composition of the gas mixture and temperature. Cracks were observed after the stage of internal oxidation. Stress corrosion test revealed that the 4330 casceptible to stress corrosion cracking in CO-CO $_2$ in the presence of moisture. The cracking is transgranular and appears to involve hydrogen embrittlement at the crack $^{\rm tr}$

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An experimental test faci	lity has been devi	eloped to	simplate to a certain
An experimental test faci	lity has been devi	eloned to	simulate to a cort

degree in a laboratory the loading and thermal environment experienced by gun barrels in automatic weapons. The test facility is capable of pressurizing hollow thick-wall cylinders cyclically at a rate of 550-600 cycles per minute and at pressures of 3500 Eg/cm². The rise time of the pressure pulse is less than 1 millisecond (atrain rates of about 3/second) and test temperatures are 260°C, 538°C and 815°C. Temperature is held constant during the test.

An automatic air driven hammer is used as the energy source to provide the cyclic loads and a solid loading medium is used to transmit pressures in the specimen. This report discusses the background of the program, the development of the apparatus and the results to date.

The facility was initially designed and built to test potential gun barrel materials and configurations. Currently being tested are specimens cabricated from CG27, Udimet 700, and conventional Cr-Mo-V steel.

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I ABSTRACT The simple thickness modes for laminated media with layering both parallel and perpendicular to the plate free surfaces are studied according to the "effective diffness" theory and the results obtained are compared to results found from the "offective modulus" theory. The importance and effects of the number of layer pairs for layering parallel to free surfaces and of the ratio of plate thickness to the thickness of a layer pair for layering perpendicular to free surfaces on dimensionless. "effective stiffness" frequencies are considered. The various "effective stiffness: and "effective modulus" frequency equations have been solved for a stiff matrix-stiff reconferring layer material and for a soft matrix-stiff reinforcing layer material; he results are presented in graphs depicting the variation of dimensionless frequency with changes in dimensionless thickness ratio. For a small number of layers parallel to the free surfaces and for small values of thickness ratio, y, for laying perpendicular to the free surfaces, the microstructure effects included in the "effective stiffness" theory become dominant and the resulting modes differ considerably from the corresponding "effective modulus" theory modes. However, for a large number of layers parallel to the free surfaces and for large values of thickness ratio, y, for layering perpendicular to the free surfaces, the "effective modulus" theory gives results in excellent agreement with the "effective stiffness" theory.

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A series of tests were conducted to determine the most feasible configuration for an artillery primer that would be suitable for both hand and automatic feeding. Various fillers were also tested to obtain an optimum ignition train. Because of their interrelation, various firing mechanism characteristics were considered, with a more compatible cannon initiator (firing unit) - propellant ignition train interface being achieved.

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W. E. Lorensen			
D. P. Kendall			
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ABSTRACT			
The stress intensity factor for	a thick-wal	led cvlind	lrical section with a
straight, radial crack has been obtained by	y a modified	boundary	collocation method.
The results obtained by this method are in	good agreem	ent with p	previously obtained
experimental results. The application of	this method	to other c	component configurations
can give an accurate K-calibration.			1
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MINIMUM EFFECTIVE COST DESIGN OF COM	POSITE CYLINDRIC	AL PRESSUR	E VESSELS RELATED TO
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
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13. ABSTRACT			
The dimensions of a composit	e gun tube consi	sting of a	cylindrical liner and
a cylindrical jacket of dissimilar ma			
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pressures are determined theoretically.

The dimensions are optimized with respect to effective cost which is defined in terms of both material cost and cost per pound of weight to the external system (penalty factor) within constraints imposed on the stress levels reached in liner and jacket through a yielding criterion.

Results are presented for a steel liner - glass epoxy jacket composite tube for a variety of costs per pound to the external system. Comparisons are made with respect to minimum weight design and conventional tube designs.

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blast waves, scaling formulas are derived for evaluating the distribution of peak pressures along the gun axis and at some slant distances. Basic input data are those as given by the breech pressure, nossle expansion ratio, and

firing duration. Calculations of this investigation are straightforward and self consistent.

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The stress field in a hollow tube with annular fins integrally machined on its outer surface was determined by the finite-element technique (NASTRAN) and an approximate one-dimensional model. Some previously unreported experimental photo-elastic results are also presented and good agreement is shown between all three methods. Two FORTRAN program listings are included.

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existing computer models of automatic weapon	ons. Included in t	his report is a listing of
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DYNAMIC STRESS INTENSITY FACTOR FOR AN L	INBOUNDED PLATE	HAVING CO	DLLINEAR CRACKS
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The steady-state vibration of an infinite plate with collinear cracks is considered for low frequency cyclic loading. The formulation of the mixed boundary value problem leads to a dual trigonometric series. The Schwinger's method gives an automatic perturbation scheme. The dynamic stress intensity factor is found to be higher than the corresponding static one. The inertial effect on the stress intensity factor becomes significant only when the frequency of the external load is close to that of the shear wave.

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The mode of loss of stability of a hinged-hinged beam subjected to a concentrated, transverse follower force applied at the center of the beam is considered. Due to the nature of the nonconservative applied load, the flexural and torsional deformations of the beam are coupled. The effects of warping rigidity and internal and external damping have been included in the differential equations of motion. The stability problem is solved in an approximate manner by means of an adjoint variational principle. Several graphs are presented to demonstrate the effect of the various daming and rigidity parameters on the value of the flutter load. These results reveal that in the absence of external damping, the value of the flutter load becomes arbitrarily small as the internal damping parameter associated with flexure tends to zero.

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K CALIBRATION FOR "C" SHAPED FRAC	TURE TOUGHNESS SPECIA	MENS OF V	ARIOUS GEOMETRIES
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D. P. Kendall	_		
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13. ABSTRACT			

Prior collocation results are combined with new collocation data and analyzed using two parameter data approximation methods and fracture mechanics methods. A general K calibration is obtained for "C" shaped specimens which have outer to inner radius ratios, $W = r_2/r_1$, between 1.4 and `.5.

The K calibration for "C" share—pecimens is found to depend on the load eccentricity to specimen thickness ratio, x/t, as well as the usual crack depth to specimen thickness ratio, a/t. The K results are presented as tabular and plotted values from a cubic spline surface used to approximate the collocation data and as a polynomial approximation of the collocation data over a more limited range of x/t.

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A PHENOMENOLOGICAL DESCRIPTION OF CE		OURING	HYDROSTATIC EXTRUSION
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A detailed metallographic investigation of the phenomenological development of central burst defects during hydrostatic extrusion was conducted. The characteristic extrusion pressure versus billet-displacement curve of extrusions containing center burst defects was periodic; each periodic segment consisted of a constant pressure part during which the extrusion velocity was slow followed by a decreasing pressure part during which the extrusion velocity was rapid. It was established that during the part of the cycle exhibiting slow billet movement, near the billet centerpine beyond the end of the die deformation zone, small microcracks formed, linked-up by tensile fracture and formed a rather large cone shaped defect exhibiting little crack opening displacement. During the portion of the periodic cycle exhibiting rapid billet movement, the cone shaped defect developed into a typical central burst defect by shear fracture at the crack tips. It was established that the volume of material immediately behind the rather large cone shaped defect, present in the deforming billet at the end of the slow velocity part of the periodic cycle, behaves as a rigid body thereby forcing the material in the die deformation zone near the die surface to squirt by this rigid body as it moves through the die orifice. The entire central burst defect after the rapid forward billet movement lies beyond the end of the die deformation zone and thus, with further extrusion, the entire cycle can repeat. The squirting action of material past the rigid body was responsible for both the shear fracture near the crack tips and the large crack opening displacement of the central burst defect.

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element method, NASTRAN. The model is desc			
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12 SPONSORING MILITARY ACTIVITY

U.S. Army Weapons Command

A MATHACT

For study the distribution of the heat affected zone in the here surface of each tubes, a 105mm M157 howitzer fired tube was examined. Twelve sections along the length of the tube were obtained, each section being examined at four positions. The distribution of heat affected zone from origin of rifling to about 30 inches beyond seems to support the temperature profile calculations of Nordheim et all, who calculated a here surface temperature of 1000°C at the origin of rifling and 800°C at about 25 inches beyond. A heat affected zone was observed near the muzzle. This phenomenon appeared to result from friction between the projectile and the hore surface.

The literature pertinent to a study of heat affected zone development is reviewed. An attempt is made to interpret the data in terms of the chemical and chermal history of the bore surface.

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The mechanical behavior of pure					

or one compositions has been observed over a range of superimposed hydrostatic presores. Resetts indicate that maxima in ductility (as measured by percent reduction in area at the tracture surface) in specimens tested at atmospheric pressure occur at compositions bordering pure tin and the cutectic composition. At sufficiently high passures and compositions failed by rupture, i.e. necking to virtually 190% RA. For gree bessatta, pressure was observed to retard failure due to the formation of cracks twin a rain bouncary intersections; this result was consistent with the hypothesis to do the object of pressure is to shift the mode of crack propagation by decreasing the normal tensile compenent of stress acting on a crack.

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-	Propellant Additive ABSTRACT (Continue on reverse side if necessary on	nd Identify by black number			
20.			te the wear reducing effect of		

titanium dioxide propellant additive with other weapon characteristics. The amount of reduction in wear is found to be related to projectile muzzle velocity, and an equation is developed which predicts the effect of TiO, on wear in a can-

An existing method for estimating the average wear rate over the life of a

weapon is revised to include the effect of TiO2 additive. Wear rates computed with the revised method are compared with observed year for several artillary

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A computer model has been prepared to assist in the analysis of reliability test data. Essentially, the model computes point estimates and confidence limits for many reliability of components, subsystems, and systems from component failure data. The main features of the model are: 1. Performs goodness-of-fit tests to determine the best fit probability distribution of component failure times, 2. Computes maximum likelihood estimates of distribution parameters, 3. Computes point estimates of reliability for the renewal nonconstant failure rate case, and 4. Computes lower confidence limits for component, subsystem, and system reliability for the constant failure rate case.

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4. TITLE (and Substite) STUDY OF FLUTED CHAMBERS FOR 20MM AUTOMATIC GUN, M139		5. TYPE OF REPORT & PERIOD COVERED
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7. AUTHOR(*) C. Perko		AMCHS No. 3548.12.283.00.01 DA Project No. 1x654604D258
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Automatic Weapons		Lubricators
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The tendency of the Automatic Gun, 20mm, M138, to fail to extract the first round of an attempted burst was eliminated by the addition of an automatic ammunition lubricator. However, problems of space limitation arose which were subsequently solved by eliminating the lubricator and using Mi39 barrels with fluted chambers instead.

Tests of three such barrels demonstrated that the use of fluted chambers completely eliminated the failure-to-extract-a-fired-case malfunctions.

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The previously developed velocity corrected effective stiffness or microstore plate theory is utilized to study the flexural vibrations of simply supports annular plates and comparisons are made to an effective modulus plate theory. In sold case frequency equations for simply supported edges are developed by passing that ions harmonic in both length and width through the differential equations while adomatically satisfying the conditions for simple supports. Careful consideration of the variations of dimensionless frequency with such dimensionless parameters width-to-thickness ratio, number of layer pairs, density ratio, thickness ratio, and elastic ratio and such results are discussed graphically.

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A study of the feasibility of rels for rapid fire weapons was in barrels at 100 ksi and muzzle vel plotted. Wall ratios and thickness of 500°F, 700°F, and 900°F and 100	f designing high nitiated. Pressu locities in the research	pressure (70 to 100 ksi) bar- re-travel curves for 30mm ange of 2800 to 4400 fps were operating at bulk temperatures	

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A relative optimization of a generalized non-dimensional form of the criticizered Euler beam is accomplished by the application of an adjoint variational principle in conjunction with a generalized Ritz procedure. Considerable weight reductions are shown to be possible within the bounds of imposed constraints for a two term Ritz approximation of Hauger's problem.

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In conjunction with the differential equations of coupled thermoelasticity with initial stresses, adjoint variational principles have been formulated in this report by introducing a set of adjoint differential equations. The natural and imposed boundary conditions for the original and the adjoint problems are obtained also with respect to each variational principle. These results can be used as basis for the finite element or other Ritz type of approximations to solve dynamic stability problems with nonconservative loads.

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The extensional vibrations of simply supported rectangular plates are considered from the viewpoint of the recently derived "effective stiffness" velocity corrected Sun plate theory by passing solutions harmonic in both plate width and length farough the differential equations of motion and boundary conditions such that the foundary conditions for simple supports are automatically satisfied. The results are compared to extensional frequencies for a reduced "effective modulus" velocity corrected Sun plate theory. It is concluded that for extensional vibrations a higher order approximation in going to the plate theory is necessary to bring out the effects of microstructure which are present in the continuum theory.

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Using the Griffith-Itwin criterion, incipient paths of propagative of such a crick were obtained from the maximum value of the energy release rate. To check the validity of the results, as experiment, shach gives a pure mode if consisting at the tip of the crack, was devised. The results were in excellent approximate with the theory. The energy release rate, in parametric form, can be used for any time selected to mode I and mode II loading conditions. To the authors' knowledge seth an expression for the energy release rate does not exist in the literature.

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The errors in estimating muzzle velocity associated with the regression equation are found to be smaller than when using the Kravitz method. The regression equation appears to offer several additional advantages over the Kravitz method.

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In many boundary value problems involving triple integral equations at tracker series relations, it is required to solve a single singular integral equation with constant but unknown limits of integration. In this paper we present a variational method to determine approximately the bounded unknown function, if it exists, together with the unknown limits of integration for a type of such singular integral equations. The method is used to recover the exact solution of an integral equation and is applied to a contact problem in the theory of elasticity which is intractable otherwise.

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1 ABSTRACT			

Two mathematically consistent solutions to the strains and displacement or a partly plastic, annular plate stressed by internal pressure are obtained according to the deformation theory of Hencky and to the flow theory of Prandtl-Reuss. In both cases, the material is assumed to be elastic, perfectly plastic and obeying the Miscs yield condition. It is shown that one solution is expressed in closed form and the other, in terms of simple integrals. A quantitative comparison of two theories is given and the effect of compressibility is discussed.

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On 6 February 1972, 175mm Gun	M113A1, Tube SN	7101, Breech SN 4970, was
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13 ABSTRACT

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A computational scheme is derived for describing stable geodesic curves on surfaces of revolution, where "stable" refers to the particular geodesics along which a flexible filament may be wrapped without lifting from the surface or slipping.

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cylinders have been tested using the genera				
cyrination mare been tobeen using the genera	coot proce.			

A wide range of specimen sizes were tested and no significant size effect on the fracture toughness, as measured by this specimen, was found.

Crack growth during fracture toughness tests was measured using an ultrasonic technique. Based on these results and on a compliance analysis, the use of a 5 percent secant offset fracture criterion is recommended for this specimen.

Standardized specimen dimensions for utilization of the "C" shaped specimen for testing a variety of chick-walled cylinders are recommended.

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containing a hole under tension or bending.	In total to	cy compos	ite material Strips	
modulus ratio lamina orientation and fiber	. In total, to	n compin	ations or constituent	
modulus ratio, lamina orientation and fiber diameter to strip width ratio were investi	r volume rract:	ion, and	three values of hole	
means of electric menictures foil commis-				

means of electric resistance foil strain gages, and analytical results from the NASTEAN, finite element analysis. It appears that stress concentration could be minimized by employing angle ply instead of uniax' if or cross-ply, by reducing constituent moduluratio, and by adjusting fiber volume fraction. Further work is necessary in order to optimize these parameters.

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"LW TECHNIQUES IN MEASURING PLASTIC STRAIN IN A MEMORY MATERIAL

4 HER REPTIVE NOTES (Type of report and inclusive dates)

Technical Report

R. V. Milligan

A REPORT DATE

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1 SUPPLEMENTARY NOTES

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Reprinted from Instrument Society of America, ASI 73239 (187-192),1973

U.S. Army Armament Command

A Nickel-Titanium memory material was studied for the purpose of characterring its stress-strain behavior, energy absorption capacity, and cyclic response. Instrumentation problems encountered in the testing of this unique material are discussed from the standpoint of thermal recovery effects on strain readings from strain gages and LVDT-type extensometers. Nickel foil type temperature sensors were used to measure surface temperatures from heat generated in the course of plastically straining the material. In addition, the sensors also monitored the heat applied to the specimen to effect thermal recovery from the plastic strain. Temperature-time curves using ${f a}$ strip chart recorder exhibited possible phase changes occurring in the material during thermal recovery after the half cycle of straining.

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13 ABSTRACT			******************************
Toughening of organic matrix mate			
tated rubber particles as the discontinuous			
consisted of recording the work required (a			
cantilevered cleavage specimen of epoxy mat is also presented from ASTM tensile tests t			
modulus and ultimate tensile strength cause			. Succession in Clubtic
land and a second of the secon			
Results are presented for three i			
hardeners while holding rubber additions at			
filament winding or casting of composites	snow benefic	iai increa	ses in toughness.
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Unclassified Security Classification DOCUMENT CONTROL DATA - R & D (Security classification of title, body of abstract and indexing annotation must be entered when the overall report to classified) 24, REPORT SECURITY CLASSIFICATION Watervliet Arsenal Watervliet, N.Y. 12189 RELATIVE OPTIMIZATION OF HAUGER'S PROBLEM WITH CIRCULAR CROSS-SECTION DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Report 5. AUTHOR(3) (First name, middle initial, last name) Charles R. Thomas 74. TOTAL NO. OF PAGES 70. NO OF REFS 40 October 1973 BE. CONTRACT OR GRANT NO. SE. ORIGINATOR'S REPORT NUMBER(S) AMCMS No. 611101.11.84400.02 R-WV-T-6-44-73 DA Project No. 1T061101A91A 8b. OTHER REPORT NO(8) (Any other numbers that may he seat great this report) Pron No. A1-3-50013-M1-M7 AD-771 173/2GI 10 DISTRIBUTION STATEMENT Approved for public "elease; distribution unlimited.

II SUPPLEMENTARY NOTES

A relative optimization of Hauger's problem with a circular cross-section is accomplished by the application of an adjoint variational principle in conjunction with a generalized Ritz procedure. Considerable weight reductions are shown to be possible within the bounds of imposed constraints for a two term Ritz approximation of Hauger's problem. The circular cross-section optimization is shown to yield a relatively lower mass than a corresponding procedure for a rectangular cross-section.

12. SPONSORING MILITARY ACTIVITY

U.S. Army Armament Command

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With little actual effort and no r theory for laminated composite beams is obt				
flexure equations for composite plates. Re				
are shown to be directly applicable to beam elastic constants.	problems in	Slight c	nanges are made in the	
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ABSTRACT				
The kinematics of rotating deform w is postulated. The general equations	able solids are d	evelope	ed, and a conserv	atro

on out a fixed axis are obtained from this conservation law, which then serves as the theoretical basis for the derivation of suitable heam theories for rotating beams and shafts subjected to conservative and non-conservative loads. The effects of internal and external damping as well as gyroscopic inertial forces are included in the formulation.

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Midwestern Mechanics Conference: 26.				
11 ABSTRACT				
In this paper we have investigat	ed the nagure	of stres	s singularities as ost	
ated with a crack inclined to a bimaterial				
The stress singula ities were obtained fro				
equation. Careful study of these results	indicated a p	hysical p	aradox. We could for a	

no angle of inclination of the crack tip to the interface for which the singularity had the same order as that of a crack tip lying in either of the individual materia:

The problem was then reformulated incorporating boundary layer effects viscouple stress floory. The most dramatic result found was that there are only two possi - engles of inclination of a crack to the interface for which the singular stress field of a crack in a homogeneous material could be preserved. This suggest that there are only two possible paths of propagation of a crack as it approaches at interface.

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II ABSTRACT				
A series of laboratory isoth and characterize the low-temperature transpared cylindrical forgings for pressure impact energy transition curves were deduced. Of the three microstructures in optimum combination of strength and tou oped during isothermal transformation,	ransformation prevessels. Tensetermined for the avestigated, temporary tenses. The terminels.	oducts or ile prope e various pered mar mnered ba	microstructures in erties, hardness, and microstructures pro- tensite provided the inite structure down.	

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A NON-LINEAR FORMULATION OF THE EQUATIONS	OF MOTION O	F A ROTATI	NG BAR		
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13 ABSTRACT					
The non-linear equations of motion					
angular velocity about a transverse axis ar					
bar is assumed to consist of two parts: (i					
with the undisturbed "equilibrium" configur					
of stress associated with the disturbed mot	ion about th	ne configur	ation of undisturbed		
"equilibrium." The equations for the equil	ibrium state	e and the d	listurbed motion are		
separated and linearized, neglecting non-li					
displacements. As examples of the theory d					
longitudinal and flexural deformations of a	rotating ba	ar carrying	a tip mass are de		
rived. The longitudinal displacement and s	tress are sl	hown to bec	ome unbounded at		
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13 ABSTRACT			Commercial About 122 12			
In the Bayesian approach to deter						
hood function is often used as the conditional distribution of sample outcome given the population parameters. For the more difficult problems involving quantities which						
are functions of more than one population						

In the Bayesian approach to determining inferencing information, the likelihood function is often used as the conditional distribution of sample outcome given the population parameters. For the more difficult problems involving quantities which are functions of more than one population parameter, use of the likelihood function can lead to very tedious computations. Computational efficiency can be improved in many instances if the distribution of estimators is used rather than the likelihood function. The use of the estimator distribution in determining Bayesian intervals is discussed with application being made to the Weibull mean. Exactness from a classical frequency viewpoint of the Bayesian intervals assuming uniform priors was also studied.

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The work presented is an extension of the Watervlict Arsenal Report "Thotoelastic Stress Analysis of Conventional and Serrated Slide Block Breech Designs", WVT-6830 by T. F. MacLaughlin. The current work is an analysis of two more possible designs for slide block breeches. The "Open Jaw" design is a possible lightweight configuration and the "90° U" would be useful in some cases where space is limited. The variation of fillet stress along the fillet is reported for all the block cavity fillets along with stresses at other points of interest. The lateral deflection of the sides of the breech ring is also reported.

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13 ABSTRACT	<u></u>					
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∧ thermistor varies the frequency	or a tiny o	scillator	mounted on a gun tube.			

A thermistor varies the frequency of a tiny oscillator mounted on a gun tube. The temperature signal is received 6 inches away. This avoids the breakage of thermocouple wires because of recoil.

A thermistor causes a circuit to oscillate when a gun tube reaches 350°F. One wire, fastened to the gun mount instead of the tube, allows a small receiver to warn personnel when the critical temperature is reached.

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